

**Convective-scale Warn-on-Forecast:  
The Severe Weather Forecast Improvements Project**



**Summary of Year Two Research Activities  
March 2011 through February 2012**

## Executive Summary

Increasing lead time and accuracy for hazardous weather and water warnings and forecasts in order to reduce loss of life, injury, and damage to the economy, is one of the main objectives of the weather and water strategic mission goal for the National Oceanic and Atmospheric Administration (NOAA). Trends in yearly-averaged tornado warning lead time suggest that the present weather warning process, largely based upon a *warn-on-detection* approach using National Weather Service (NWS) Doppler radars, is reaching a plateau and further increases in lead time will be difficult to obtain. A new approach is needed to extend warning lead time in which probabilistic hazard guidance is provided by an ensemble of forecasts from convection-resolving numerical weather prediction models. This convective-scale probabilistic hazardous weather forecast system is called *warn-on-forecast*.

This document summarizes the research efforts that will be conducted during the second year of the warn-on-forecast project from March 2011 through February 2012. Efforts during the first year were largely pointed towards laying the foundation for the program's success, such as hiring needed staff and strengthening our collaborative research activities. The research efforts during this second year show more clearly the directions the project is taking and how the different groups are working together. The activities of each organization that receives funding from the warn-on-forecast project are summarized in the following sections, along with any deliverables. This document is required as part of the annual planning process for the project and is an important component of the project management structure.

The warn-on-forecast project represents a collaborative effort across several NOAA units and academia. The project is led by the National Severe Storms Laboratory, with substantial NOAA contributions from the Earth System Research Laboratory, the Storm Prediction Center, and the Norman NWS Forecast Office. Academic collaborators are the Center for Analysis and Storms and the Social Sciences Woven into Meteorology Program within the Cooperative Institute for Mesoscale Meteorological Studies at the University of Oklahoma.

## **2011-2012 Research Activities**

### **NOAA/OAR/National Severe Storms Laboratory**

During the second year of the warn-on-forecast project, the National Severe Storms Laboratory proposes to accomplish the following tasks:

- Continue to develop quality-controlled data sets for use in assimilation and quality control (QC) algorithm testing. This work involves the manual editing of radar data to fix velocity de-aliasing errors and the removal of reflectivity artifacts. Each case may have data from multiple WSR-88D radars. We will also gather supplemental data sets for each case, such as model analyses and forecasts, surface and upper-air observations, and satellite data. All the data will be made available to project participants over the Internet.
- Using the results of the automated radar QC method survey from the first year, obtain or develop software to apply these automated techniques to radar observations in a sequential approach. The intent is to be able to pass the radar observations through a clutter filter followed by a filter to remove non-precipitating echoes followed by one or two de-aliasing algorithms in order to remove a large fraction of the questionable observations prior to either manual editing or assimilation in numerical models.
- Develop radar data converters to allow participants to convert between the most common radar data formats.
- Create analyses using a three-dimensional variational (3DVAR) system to assimilate radar observations in real time over several 200 x 200 km domains in support of the Hazardous Weather Testbed (HWT) Experimental Warning Program. Examine the 3DVAR analyses during the HWT to assess the value of these analyses in comparison to other radar products available.
- Continue real-data case studies using an ensemble Kalman filter to assimilate WSR-88D and other routine observations into a ~2 km grid spacing configuration of the Weather Research and Forecasting (WRF) model using the Data Assimilation Research Testbed (DART) square root filter software developed at the National Center for Atmospheric Research. Explore ability to provide these data for displaced-realtime experiments in HWT.
- Explore the potential for using a 3DVAR approach to start an ensemble Kalman filter data assimilation system.
- Continue development of a hybrid 3DVAR approach for radar data assimilation.

- Evaluate impacts of microphysics parameterization on radar data assimilation analyses and forecasts.
- Continue to study the predictability of severe thunderstorms by estimating the uncertainty of the environments known for producing severe convective thunderstorms and assessing how these uncertainties influence thunderstorm evolution.
- Begin developing a framework for the inter-comparison of different radar data assimilation schemes in collaboration with ESRL/GSD. Develop a website for sharing data for selected cases of interest.
- Collaborate with the other project partners in exploring complex issues related to the frequent updating of convective-scale models, both deterministic and ensemble systems. Begin to look at ways to include satellite observations in the assimilation process.
- Continue to lead effort with other warn-on-forecast partners to develop a unified plan for social science research activities.

#### Deliverables:

- Quality controlled and supplemental data sets for 11 June 2009 VORTEX2 case completed and available to project partners.
- Successful completion of the HWT Experimental Warning Program with assessment of the performance of the 3DVAR analyses for assisting warning operations.
- Assist Norman NWS FO in using 3DVAR in their hourly WRF model forecasts.
- Archival of the 3DVAR assimilated fields and corresponding data sets (radars, etc.) from real-time operations.
- Development of needed radar data converters.
- Development and application of automated radar QC methods in sequential form and testing on available manual QC data sets.
- Initial results from real data applications of ensemble Kalman filter to the assimilation of radar observations from a supercell thunderstorm case and a mesoscale convective system case.
- Develop a website for sharing data for selected cases of interest.
- Hold fall 2011 radar data assimilation meeting with NSSL, GSD and CAPS (if funding available).

## **NOAA/OAR/ESRL/Global Systems Division**

During the second year of the warn-on-forecast project, the Global Systems Division proposes to accomplish the following tasks:

- Finalize code necessary to provide forecast output from the High-Resolution Rapid Refresh (HRRR) model every 15-min during the 0-3 h forecast time period. These 15-min output files will be used to provide boundary conditions for warn-on-forecast model ensemble testing and evaluation. Provide 15-minute output for cases in which NSSL is providing manual radar data quality control.
- Continue testing the direct application of the Digital Filter Initialization (DFI) radar-based technique at the 3-km resolution of the HRRR. Explore the DFI approach when radar data at multiple times are used in the assimilation window.
- Begin developing a framework for the inter-comparison of different radar data assimilation schemes in collaboration with NSSL.
- Collaborate with NCAR on VORTEX2 retrospective modeling and numerical weather prediction.
- Apply storm-scale ensemble sensitivity analysis to a severe weather event.
- Document the operational procedures and uses of current AWIPS and N-AWIPS capabilities and functionality that support operational severe weather watch and warning programs.
- Continue to work with warn-on-forecast partners in developing a unified plan for social science research.

### **Deliverables:**

- HRRR gridded forecast output produced at 15-minute intervals during the 0-3 h forecast time frame and made available to project partners for 5 June and 11 June 2009 cases.
- Continued testing of DFI within HRRR.
- Report documenting the operational procedures of WFO and SPC for determining and generating severe weather watches and warnings.
- Collection of warning and verification information from selected WFOs.
- Initial results from a storm-scale ensemble sensitivity analysis.

- Test of a prototype displaced real-time evaluation system for warn-on-forecast that can be used to assess techniques and capabilities.

## **NOAA/NWS/NCEP/Storm Prediction Center**

During the second year of the warn-on-forecast project, the Storm Prediction Center proposes to accomplish the following tasks:

- Work towards meeting warn-on-forecast guidance in the 1-3 hour time frame by developing finer spatial and temporal probabilistic guidance and testing it in the HWT.
- Explore new ways to visualize data on specific storm properties and model summaries and test in the HWT.
- Add convection initiation desk to the HWT.
- Work with other warn-on-forecast partners to develop a unified plan for social science research. Explore the role of the human in the forecast process and ways to study how we can best communicate the severe weather threat to the public in collaboration with the SSWIM group.

Deliverables:

- Successful completion of the 2011 Hazardous Weather Testbed, Experimental Forecast Program with a convection initiation desk.
- Assessment of new visualization approaches within the HWT
- Development of a social science research project in collaboration with SSWIM.

## **NOAA/NWS Norman Forecast Office**

During the second year of the warn-on-forecast project, the NWS Norman Forecast Office proposes to accomplish the following tasks:

- Provide hourly-updated WRF model forecasts to the HWT during spring 2011 for evaluation. Provide guidance to other NWS offices in best practices for using the forecasts.
- Compare forecasts starting from a LAPS analysis with those starting from a 3DVAR analysis.
- Work with other warn-on-forecast partners to develop a unified plan for social science research. Develop a survey to evaluate efficacy of call-to-action statements in tornado warnings in collaboration with the SSWIM group.

Deliverables:

- Successful delivery of hourly-updated WRF model forecasts to the HWT.
- Initial comparison of forecasts started using LAPS versus those started using 3DVAR.
- Survey questions completed to evaluate efficacy of call-to-action statements in tornado warnings.

## **University of Oklahoma/Center for Analysis and Prediction of Storms**

During the second year of the warn-on-forecast project, the Center for the Analysis and Prediction of Storms proposes to accomplish the following tasks:

- Enhance the ARPS EnKF system for multi-scale observations (e.g., radar, surface and upper-air) and evaluate it using one of the VORTEX2 cases. This EnKF system uses the ensemble square root algorithm (EnSRF).
- Develop a hybrid 3DVAR-ensemble system based on the ARPS 3DVAR and ARPS EnKF and evaluate the performance relative to the pure 3DVAR and pure EnSRF algorithms using observing system simulation experiments with emphasis on the assimilation of radar observations.
- Develop a local ensemble transform Kalman filter (LETKF) system and implement it within the ARPS EnKF framework. Inter-compare the performance and computational costs of LETKF and EnSRF algorithms for the convective-scale radar data assimilation problem with observing system simulation experiments.
- Develop an interface for the ARPS EnKF data assimilation system with Advanced Research WRF (ARW) model.

Deliverables:

- Enhanced ARPS EnKF system for multi-scale observations (e.g., radar, surface and upper-air) completed and testing started.
- A local ensemble transform Kalman filter (LETKF) system completed and implemented within the ARPS EnKF framework.
- An interface for the ARPS EnKF data assimilation system with Advanced Research WRF (ARW) model completed and made available to project partners.

## **University of Oklahoma/Social Sciences Woven into Meteorology Program**

During the second year of the warn-on-forecast project, the Social Sciences Woven into Meteorology Program proposes to accomplish the following tasks:

- Begin interviewing administrators at K12 schools to gain insight into which sources of weather information are most useful schools and determine the potential impacts of longer lead times for decision making.
- Work with other warn-on-forecast partners to develop a unified plan for social science research and collaborate on projects of mutual interest.

Deliverables:

- Initial results from interviews of K12 school administrators.
- Annotated bibliography of social science literature deemed relevant to the WoF project.